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Article



## Productive and economic response to concentrate supplementation by grazing dairy cows at high stocking

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### Abstract:

Small-scale dairy systems contribute to ameliorate rural poverty and to local milk supply. Their sustainability is limited by high feeding costs, mainly from purchased concentrates (CC); whereas a higher reliance on quality forage may improve profitability; but high stocking rates may justify high CC use. The objective of this work was to assess the productive and economic response by grazing dairy cows to levels of CC under grazing of ryegrass–white clover pastures under high stocking rate (4 cows/ha). Six Holstein milking cows were replicated assigned 3 X 3 Latin Square arrangements. Daily milk yield and composition were recorded, and feed intake estimated from utilised metabolizable energy. Treatments were: T1= 1.0 kg T6= 3.0 kg and T6= 6.0 kg concentrate/cow/d. There were significant differences ( $P<0.05$ ) for milk yield, with T6 having higher yields than T1 and T3. There were no significant differences in milk protein or fat content among treatments ( $P>0.05$ ). Herbage intake was significantly ( $P<0.05$ ) lower in T6, with no

differences ( $P>0.05$ ) between T1 and T3. There were no differences in margins over feeding costs, but feeding cost per kg of milk was 2.2 times higher in T6 compared to T1, and margin per kilo of milk was 26 % higher in T1 than T6. Although milk yields are higher with T6, T1 and T3 require less expenditures and margins are similar. Supplementation may alleviate high grazing pressure that deteriorates pastures, ensuring the long-term sustainability of small-scale dairy farming systems.

**Key words:** Milk, Supplements, Concentrate, Intake, Stoking rate, Cost.

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## Introduction

Small-scale dairy systems in Mexico are a rural development option since they enable farming families to overcome poverty indices<sup>(1)</sup>. These systems are important in many areas of the world with common features to the highlands of Mexico<sup>(2)</sup>, like in other Latin American countries as in the Andean highland regions of Peru<sup>(3,4)</sup> and Uganda<sup>(5)</sup>.

In Mexico, they are defined by small farms with herds between three and 35 cows plus replacements, and rely on their family labour<sup>(6)</sup>. Their sustainability is jeopardised by high feeding costs in the face of stagnated prices for milk, mainly due to their reliance on external inputs of which bought-in commercial compound concentrates represent the highest proportion of costs, since farmers believe that high levels of concentrate supplementation are essential for milk production, even at the moderate milk yields in these systems. Therefore, the economic scale limits their sustainability<sup>(6)</sup>.

A higher use of quality home-grown forages may increase the profitability and hence sustainability of these systems, as is the case for intensive grazing of temperate pastures in farms with access to irrigation, that has been shown to reduce feeding costs in these systems<sup>(7)</sup>.

However, one limitation of grazing dairy cows is the low intake of dry matter<sup>(8)</sup>, particularly under high grazing pressure, so that concentrates may be required in these conditions to sustain milk yields. Small-scale dairy systems traditionally have more cattle than the carrying capacity of their small farms with stocking rates over 3.0 cows/ha of agricultural land<sup>(6)</sup>, so that a high concentrate use may be justified in these systems.

Therefore, the objective of this work was to assess the productive and economic response of grazing dairy cows at a high stocking rate to increased levels of compound concentrate supplementation, as well as their effect on feed intake.

## Material and methods

The work took place in Ejido San Cristóbal, a smallholder campesino village where most families are small-scale dairy farmers, located in the highlands of central Mexico at 19° 24' N and 99° 51' W, at an altitude of 2,650 m. The region has a sub-humid temperate climate with a distinct rainy season (May – October) and dry season (November – April), and average annual rainfall of 800 – 1,000 mm and a mean annual temperature of 13°C. The experiment took place during the rainy season, from June 26<sup>th</sup> to August 27<sup>th</sup> of 2000.

A demonstration module in feeding strategies for small dairy herds was established in consultation with the community on a 1.5 ha<sup>-1</sup> plot of the local school. A local participating farmer managed the module with a herd of six local milking cows following a participatory livestock technology research approach<sup>(9)</sup> so that results were applicable by farmers in the region and other areas with similar systems.

## Experimental design

Li Treatment sequences were randomised for Square 1, and Square 2 followed a mirror image in the treatment sequences to account for carry-over effects. Cows were assigned randomly to treatment sequence in both squares following previous work<sup>(10)</sup>.

Experimental periods lasted 21 d, 14 for adaptation to diet and 7 as measurement period. Cows were hand milked twice daily at 0500 and 1800 h.

Treatments were: T1= 1.0; T3= 3.0; and T6= 6.0 kg fresh basis/cow/d of commercial compound concentrate with 16 % CP, respectively. Cows continuously grazed for 11 h/d<sup>-1</sup> with drinking water provided *ad libitum* at pasture (*Lolium perenne* and *Trifolium repens*). During nights, cows stayed indoors in a tie-stall and no feed was provided.

Milk yield was weighed daily during the 7 measurement days per experimental period with a spring balance using mean daily yield for analysis; and samples of milk taken in a morning and an afternoon milking to determine milk protein and milk fat content.

Body condition score (1 – 5 scale) was determined on the last day of each experimental period.

### **Pasture establishment and grazing management**

The 1.5 ha<sup>-1</sup> were sown with a mixed pasture of perennial ryegrass (*Lolium perenne* cv. Nui), annual ryegrass (*L. multiflorum* cv. Tama) and white clover (*Trifolium repens* cv. Pitaw). The pasture was fertilized every 4 wk with 75 kg of urea (46-0-0)/ha<sup>-1</sup>, and twice a year with 100 kg/ha of triple super phosphate (0-46-0) and potassium chloride (0-0-60), respectively. Continuous (set-stocked) grazing took place from 0700 to 1800 h daily.

### **Herbage measurements**

Estimation of net herbage accumulation (NHA) was from cutting to ground level with shears 0.5 m<sup>2</sup> (2.0 x 0.25 m) quadrants, within five exclusion cages. NHA (Kg DM ha<sup>-1</sup> d<sup>-1</sup>) was the difference between herbage cut inside the cage on d 21 and herbage found outside the cage on d 0, then cages were placed randomly in the sward<sup>(11,12,13)</sup>. Samples of cut herbage were oven-dried (60 °C) air forced for DM analysis. These dry weights were used to calculate the herbage mass on a DM basis. Herbage height (cm) was recorded with a rising plate metre twice weekly, taking 20 recordings following a zigzag pattern<sup>(10,11)</sup>.

### **Chemical composition of herbage and feeds**

Herbage was sampled by hand-plucking at the approximate height to which the cows grazed<sup>(14,15)</sup>. During each measurement period herbage and concentrate were all analysed for dry matter (DM), organic matter by ashing (OM), crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) and estimated metabolizable energy (oME) content of herbage and concentrate were from *in vitro* digestibility by standard techniques following the procedures reported<sup>(1)</sup>.

## Estimation of voluntary intake

Herbage DM intake was estimated, indirectly, once during each measurement period from animal performance results<sup>(15,16)</sup> as follows:

$$\text{Herbage DM intake (kg DM d}^{-1}\text{)} = \frac{(\text{ME}_m + \text{ME}_{my} + \text{ME}_{lwc} + \text{ME}_g) - (\text{supplement ME})}{\text{herbage ME}}$$

where,  $\text{ME}_m$ ,  $\text{ME}_{my}$ ,  $\text{ME}_{lwc}$  and  $\text{ME}_g$  are the ME requirements for maintenance, milk production, live weight change and gestation, respectively<sup>(17)</sup>, supplement ME supplied by the supplement, and herbage ME is the estimated ME concentration of herbage samples.

## Statistical analysis

Animal variables were analysed as a replicated 3 x 3 Latin Square with the following model<sup>(10)</sup>:

$$Y_{ijkl} = \mu + S_i + C_{j(i)} + P_k + t_l + e_{ijkl}$$

Where:

$\mu$ = General mean;

$S$ = effect due to squares.  $i = 1, 2$ ;

$C$ = effect due to cows within squares  $j = 1, 2, 3$ ;

$P$ = effect due to experimental periods.  $k = 1, 2, 3$ ;

$t$ = effect due to treatment.  $l = 1, 2, 3$ ;

$e$ = residual error term.

Animal response variables were analyzed using MINITAB general linear model command (2003). Multiple comparisons between least squares means were performed using the Tukey test. Pastures variables (Table 1) were analyzed with one-way ANOVA using Microsoft Excel® data analysis package.

## Economic analysis

The economic analysis was performed using the partial budget approach<sup>(18)</sup>, to determine the economic profits due to the use of supplements, exclusively for milk. Economic analysis results are expressed in US dollars.

## Results

Average temperature was 13.6°C, with a maximum and minimum of 20.5 and 6.8 °C, respectively. Total rain fall during the experiment was 332 mm, distributed as follows 139, 122 and 61 mm in EP1, EP2 and EP3, respectively.

Table 1 shows results for net herbage accumulation (NHA) per period and per day, as well as mean sward height. Net herbage accumulation and DHA in EP3 were significantly higher than in EP one and two ( $P<0.01$ ).

**Table 1:** Net herbage accumulation (NHA) and sward height

		Period			<i>P</i> =	SD
Herbage mass		1	2	3		
NHA,	kg	1073.1 <sup>a</sup>	890.0 <sup>a</sup>	2024.5 <sup>b</sup>	0.01	609.0
OM/ha/period						
Daily NHA,	kg	51.1 <sup>a</sup>	42.4 <sup>a</sup>	96.4 <sup>b</sup>	0.02	29.0
OM/ha/d						
herbage height, cm		3.0	2.4	5.5	0.21	1.6

SD= Standard deviation.

<sup>a,b</sup> Values with different superscript differ

Table 2 shows the chemical composition of the pasture herbage. Crude protein and digestibility were not different across EP ( $P>0.05$ ). Crude protein ranged from 122 to 162 (EP1 and EP3, respectively), with a mean of 147 g/kg DM. Digestibility (Dig) mean digestibility was 581 (g/kg DM). Dry matter, ash, OM, NDF and ADF were significantly different across EP ( $P<0.05$ ). Estimated metabolizable energy (eME) was different ( $P<0.001$ ) among EP, the lowest value was in EP1 (10.1), whereas EP2 and 3, were not different among each other (11.2 and 11.2 MJ ME/kg DM).

**Table 2:** Chemical composition of herbage

	Period			<i>P</i>	SD
	1	2	3		
Dry matter, g kg <sup>-1</sup>	275.5 <sup>a</sup>	346.9 <sup>b</sup>	262.1 <sup>a</sup>	0.001	45.6
Ash, g kg <sup>-1</sup>	265.2 <sup>a</sup>	230.2 <sup>a</sup>	97.6 <sup>b</sup>	0.03	0.1
Organic matter, g kg <sup>-1</sup>	734.8 <sup>a</sup>	769.8 <sup>a</sup>	902.4 <sup>b</sup>	0.001	32.3
Crude protein, g kg <sup>-1</sup> DM	160.4	121.5	161.9	0.08	75.3
Neutral detergent fibre, g kg <sup>-1</sup> DM	572.4 <sup>a</sup>	473.8 <sup>b</sup>	517.9 <sup>a</sup>	0.001	49.4
Acid detergent fibre, g kg <sup>-1</sup> DM	474.3 <sup>a</sup>	247.9 <sup>b</sup>	260.5 <sup>b</sup>	0.01	127.2
Digestibility of organic matter, g kg <sup>-1</sup> DM	602.3	559.7	NA	0.11	347.1
Metabolizable energy, MJ kg <sup>-1</sup> DM	10.1 <sup>a</sup>	11.2 <sup>b</sup>	11.1 <sup>b</sup>	0.001	0.91

\* Estimated from Menke and Steingass (1988).

SD= Standard deviation.

<sup>a,b</sup> Values with different superscript differ.

Table 3 shows the results for feed intake, with significant differences ( $P<0.05$ ) among treatments. There were no differences between T1 and T2 in herbage intake but lower intake in T6. Due to concentrate supplementation, total feed intake was not significantly different ( $P>0.05$ ) between T3 and T6, but total intake was significantly lower ( $P<0.05$ ) for T1. In time, there was a reduction in herbage intake, in Period 2, in spite of improved grazing conditions; this, lead to a significantly lower total intake ( $P<0.05$ ) in Period 2, compare to periods one and three.

**Table 3:** Feed intake by treatments and periods kg (OM/cow/d)

Intake	Treatments			<i>P</i>	SEM
	T1	T3	T6		
Concentrate	0.9	2.6	5.3		
Herbage	8.2 <sup>a</sup>	7.3 <sup>a</sup>	6.1 <sup>b</sup>	0.001	0.5
Total	9.1	9.9	11.4	0.17	0.7
Intake	Period			<i>P</i>	SEM
	1	2	3		
Concentrate	2.9	2.9	2.9		
Herbage	7.3 <sup>a</sup>	6.9 <sup>b</sup>	7.3 <sup>a</sup>	0.04	0.5
Total	10.2 <sup>a</sup>	9.8 <sup>b</sup>	10.2 <sup>a</sup>	0.001	0.7

SEM = Standard error of the mean.

<sup>a,b</sup> Values with different superscript differ.

There were significant differences ( $P<0.05$ ) among treatments for milk yields (Table 4); with no differences between T1 and T3, which were significantly different ( $P<0.05$ ) from T6 which had the highest yield.

**Table 4:** Milk yield and milk composition by treatment and periods

<b>Treatment</b>	<b>T1</b>	<b>T3</b>	<b>T6</b>	<b>P</b>
Milk yield, kg/cow/d	11.3 <sup>a</sup>	12.6 <sup>a</sup>	15.8 <sup>b</sup>	0.02
Milk fat content, g/kg	37.8	37.6	33.8	0.59
Milk protein content, g/kg	35.1	32.8	33.0	0.91
<b>Period</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>P</b>
Milk yield, kg/cow/d	-	11.3	14.1	0.11
Milk fat content, g/kg	38.5	35.6	35.5	0.60
Milk protein content, g/kg	30.6	36.3	34.0	0.11
Body condition score	1.8	1.8	1.8	

SEM = Standard error of the mean;

<sup>a,b</sup> Values with different superscript differ ( $P<0.05$ )

Table 5 shows results for feeding costs (in US dollars). Increased concentrate supplementation increased feeding costs. Total feeding costs in T6 are almost three times the feeding cost in T1, whilst milk income was only 28 % higher, which results in a feeding cost per kilo of milk 2.2 times more expensive in T6 than in T1; with figures for T3 intermediate. Profit per kilogram of milk was therefore 33 % higher in T1 than in T6.



**Table 5:** Feeding costs for milk production at three levels of concentrate supplementation (US\$)

	Treatments		
	T1	T3	T6
Cost of feed inputs:			
Concentrate	24.5	76.4	152.8
Pasture	37.5	36.4	26.3
Total feeding costs	63.0	112.8	179.1
Returns:			
Milk production, kg	1,311.3	1,459.6	1,691.8
Total returns for milk sales	388.5	432.5	501.3
Margin over feed costs	325.5	319.6	322.1
Returns / feeding costs ratio	6.2	3.8	2.8
Feeding cost, (US\$/kg milk)	0.05	0.08	0.11
Sale price of milk, (US\$/kg)	0.29	0.29	0.29
Margin per kilo (US\$/kg)	0.24	0.21	0.18

T1 = 1; T3 = 3 y T6 = 6 kg of concentrate DM cow<sup>-1</sup>/d.

## Discussion

The effect of weather condition is reflected in the chemical composition of the herbage throughout the different growing seasons. This grazing season was characterized by low herbage growth rate, short regrowth, low herbage mass availability and low herbage intake. In addition, grass development was based on vegetative growth, characterized with higher proportions of grass leaf, lower proportions of grass stem and dead material, and more digestible than other vegetative state. Temperate herbages used for dairy cows are described as high quality when chemical composition is around 180-240 g DM kg<sup>-1</sup>, 180 to 250 g CP kg<sup>-1</sup> DM, 400 to 500 g NDF kg<sup>-1</sup> DM, and 10.47 to 12.14 MJ ME kg<sup>-1</sup> DM<sup>(19)</sup>. Under the conditions of this experiment, herbage was characterized by low concentrations of crude protein, low energy and low amounts of non-structural carbohydrates and DM.

Crude protein content of pasture herbage was lower than a report in southern Brazil<sup>(20)</sup>, and lower than reports of work undertaken in the same study area<sup>(21,22)</sup>; but sufficient to meet protein requirements for moderate yielding dairy cows<sup>(23)</sup>.

Structural carbohydrate content determines digestibility, intake, and the nutritional value of forages. Average values of NDF and ADF of pasture herbage were 521.37 and 327.57 g/kg DM, respectively; lower from reports in a previous work in the same area, but during the dry season<sup>(24)</sup>.

Estimated metabolizable energy was 10.8 MJ/kg DM on average (Table 2) representing an herbage of good quality. However, this value is lower than reports of 12.3 MJ EM/kg DM in the highlands of Mexico<sup>(10)</sup>, or 11.2 MJ EM/kg DM reported in New Zealand<sup>(25)</sup>. The interaction of lower energy content and herbage availability may explain low intakes and low milk yields observed (Tables 3 and 4).

Net herbage accumulation was low during periods 1 and 2, which given the high stocking rate, resulted in a high grazing pressure and low herbage availability, with very low sward metre heights. Improved grazing conditions in terms of herbage growth and availability for Period 3, enabled cows to recover milk yields similar to those of Period 1, overcoming the loss of almost 3 kg/cow/d<sup>-1</sup> from Period 1 to Period 2 as grazing conditions deteriorated.

Difficult grazing conditions with low herbage availability and moderate milk yields resulted in low herbage intakes, which were significantly decreased ( $P < 0.05$ ) by the high supplementation rate in T6, with high substitution rates.

It has been reported that 0.31 kg/d<sup>-1</sup> of concentrate supplemented to grazing dairy cows results in a 1.0 kg DM reduction in herbage intake<sup>(26)</sup>. Nonetheless, herbage intake in the experiment herein reported was similar to reports by<sup>(27,28)</sup> with grazing dairy cows in low herbage mass pastures during winter in France, reporting a mean daily intake of 7.2 kg DM/cow.

Observed milk yields were lower than results for grazing cows reported by in the USA<sup>(26)</sup>, in the UK<sup>(29)</sup>, in southeast USA<sup>(30)</sup>, and in Mexico<sup>(24)</sup>. However, observed milk yields were similar to reports by others<sup>(27)</sup> from cows under difficult grazing conditions in western France, illustrating the fact that difficult grazing conditions limit intake, and yields, particularly during late lactation.

Milk fat contents of milk are similar to results reported in France<sup>(27)</sup>, in Spain<sup>(31)</sup>, and in Chile<sup>(32)</sup>. Although there were no statistical differences in milk fat content ( $P > 0.05$ ) there was a trend towards lower content in the high supplementation treatment T6.

Protein content of milk was higher than reports from works in Mexico with small-scale dairy farmers<sup>(33,34)</sup>, as well as higher than reports from Chile<sup>(32)</sup>; but similar to milk protein content from a study in the UK<sup>(29)</sup>.

In terms of feeding costs and returns, in spite of lower yields for T1 and T3 compared to T6, the margin over feeding costs is similar for the three treatments. However, in terms

of feeding cost per kg of milk and profit over feeding costs, T1 has lower cost and higher profit. Feeding cost per kilo of milk was 2.5 times higher in T6 compared to T1, and margin was 25 % higher in T1 than T6, with T3 showing intermediate economic results. Low feeding costs and similar margins among treatments result in a very high returns / feeding costs ratio for T1 compared to T6.

## **Conclusions and implications**

In conclusion, there is no economic benefit of increased concentrate supplementation since total margins over feeding costs are similar; and farmers need a greater cash flow to cover the increased costs of higher amounts of concentrate used. However, there is a need for long-term experiments since supplementation alleviates the grazing pressure due to high stocking rates. NHA was low resulting in difficult grazing conditions limiting the intake of cows. Forage or by-products of lower cost than commercial compound feeds may also be an alternative to sustain cow and pasture productivity. An optimal compromise in productive, economic and in the soundness of the pasture will ensure the long term sustainability of these small-scale farming systems.

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